Astronomy & Astrophysics manuscript no. grb040812v1˙0 December 23, 2004
(DOI: will be inserted by hand later)

GRB 040812 ⋆

N. Lund[1], S. Brandt[1], J. Chenevez[1], C. Budtz-Jørgensen[1], N.J. Westergaard[1], S. Mereghetti[2], D. Gotz[2], C. Kouvelioutu[3], P. Ubertini[4], and S. Patel[5]

1 Danish National Space Center, Juliane Maries Vej 30, DK-2100 Copenhagen Ø, Denmark
2 Milano
3 Amsterdam
4 Rome
5 Marshall

Received ; accepted

Abstract. GRB 040812 - version 1.0. Abstract still to be written. Please inform me of co-authors / institutions which have to be included. Please also provide improvements, clarifications, new points to the text and figures as you see fit.

Key words. Gamma Rays: bursts – Gamma Rays: observations

1. Introduction

2. INTEGRAL observations

On August 12 2004 a gamma-ray burst was detected by the IBAS burst trigger system working on real time data from the ISGRI detector aboard INTEGRAL. The nominal trigger time for GRB 040812 was at 06^h 02^m 04.6^s (UT) and the public alert from IBAS came only 16 s later at 06^h 02^m 21^s.

The light curve of the burst in four energy bands is reproduced in Figure 1. The burst duration (T90) depends on the energy range considered. It is 19 s for the 20 to 200 keV range of ISGRI and about 30 s for the 4 to 35 keV range of JEM-X.

The initial IBAS alert message (# 1548) quoted a burst position of RA: 246.49°, dec: -44.71° with an uncertainty of 2.9′, this position is only about 2′ away from the refined position: RA: 246.52°, dec: -44.71° (with a 2′ uncertainty at 90% confidence). The refined postion was communicated with a delay of about 40 minutes after an initial off line analysis (IBAS alert # 1550). Although both of the two early positions were based on the near real time solution for the attitude, no updating of the IBAS position were required after the consolidated attitude solution became available.

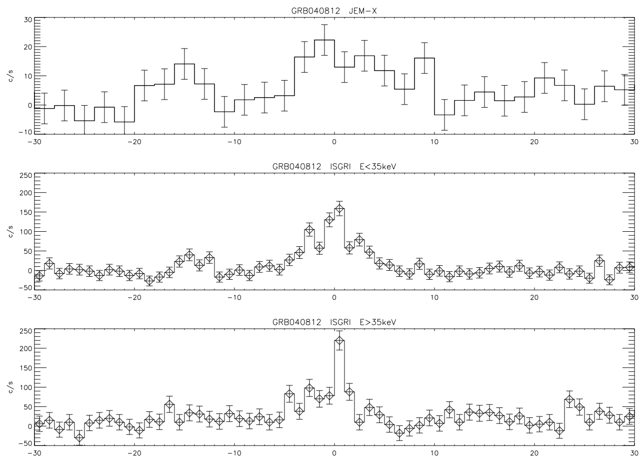

Fig. 1. Lightcurves of GRB 040812 as observed by JEM-X and IBIS

GRB 040812 was the first burst since the launch of INTEGRAL to occur inside the field of view of INTEGRALs X-ray monitor, JEM-X. It is therefore possible in this case to extend the energy coverage for the prompt emission from the burst source down to about 4 keV, compared to a cut off value around 15 keV for bursts only visible to the IBIS/ISGRI detector.

Send offprint requests to: N. Lund, e-mail: sb@dsri.dk

⋆ Based on observations with INTEGRAL, an ESA project with instruments and science data centre funded by ESA member states (especially the PI countries: Denmark, France, Germany, Italy, Switzerland, Spain), Czech Republic and Poland, and with the participation of Russia and the USA.

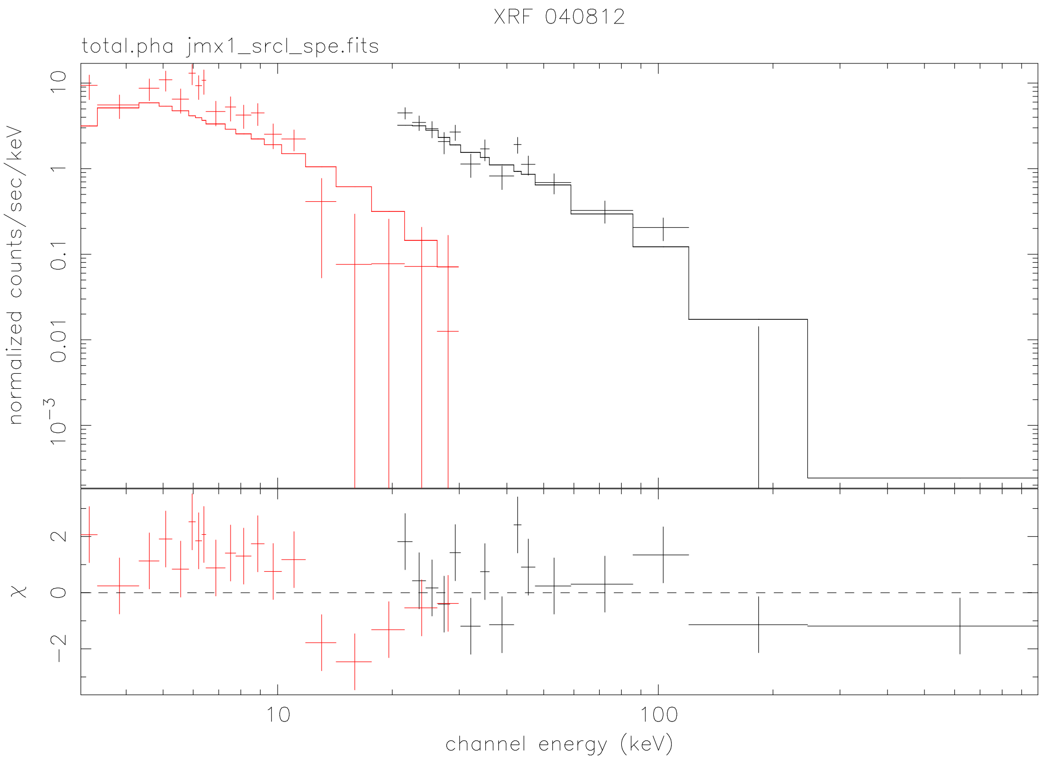

Fig. 2. Integrated spectra and combined fit for JEM-X and ISGRI

The position of the burst source can also be determined from the JEM-X data. The best JEM-X position, RA: 246.48°, dec: -44.71° with an uncertainty of 1.2′, deviates from the IBAS position but is consistent with. The error circles corresponding to the ISGRI and the JEM-X positions are reproduced in Figure 2.

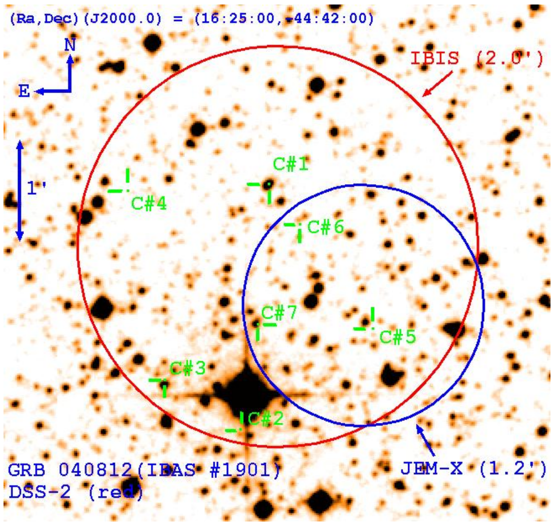

Fig. 3. Finding chart for GRB 040812 with IBIS and JEM-X error circles

The corresponding number of recorded burst photons are 1500(?) and 500 respectively in the two instruments. The integrated fluence is 2.5×10^{-7} ergs/cm^2, and the peak flux is 0.6 ph/cm^{2}s over the energy range 15 to 200 keV. This places GRB 040812 at the low intensity end among the bursts detected by IBAS. The burst exhibits spectral evolution during the burst with the lower energy emission both leading and trailing the hard emission. X-ray precursors have been seen before (ref), but is not the most common type of spectral evolution in gamma-ray bursts.

The combined spectrum from JEM-X and ISGRI is shown in Figure 2. The spectrum is fitted with an absobed power law (spectral index -2.38±0.14), the high value of the spectral index classifies this burst as an "X-ray Flash".

The limited count statistics available does not allow to perform a detailed study of the time evolution in the burst spectrum, Figure 4 (still to come) shows the evolution in two hardness ratios based on two energy bands from JEM-X and two energy bands from ISGRI.

Prompt data on GRB 040812 was also obtained with the SPI instrument on INTEGRAL. (Section to be elaborated or deleted according to discussions with L. Hanlon).

Although GRB 040812 occurred closer to the INTEGRAL pointing axis than any previous burst it still was just outside the field of view for the optical monitor, OMC. There are therefore no useful data on this burst from OMC.

Table 1. Summary of the follow-up work done on GRB 040812

Prompt emission observations					
Telescope	**Instrument (spectral band)**	**Truncated Julian Day**	**Date**	**Start Time (UT)**	**Duration (s)**
INTEGRAL	IBIS/ISGRI (20-200 keV)	13229	04 08 12	06:02:04.61 (trigger)	19 (T90)
INTEGRAL	JEM-X (4- 35 keV)	13229	04 08 12	06:02. (trigger)	40 (T90)
Follow-up observations					
Keck-I	LRIS (I)	13229	04 08 12	06:49	
Keck-I	LRIS (I)	13229	04 08 12	07:46	
ESO-VLT	(I)	23229	04 08 12	23:30	600
1.3m CTIO	ANDICAM (BRIYJK)	13230	04 08 13	00:25	180 / band
1.3m CTIO	ANDICAM (HV)	13230	04 08 13	00:25	120 / band
ESO-VLT	(I)	23230	04 08 13	23:37	600
LCO DuPont 2.5m	(I)	13231	04 08 14	00:02	
VLA	(8.5 GHz)	13231	04 08 14	03:36	
GMRT	(1280 MHz)	13333	04 08 16		
Chandra	ACIS-S (.5-8 keV)	13234	04 08 17	07:08	10000
Chandra	ACIS-S (.5-8 keV)	13239	04 08 22	09:55	10000
HST	ACS (r,i)	13261	04 09 13		
HST	ACS (r,i)	13283	04 10 05		

3. Follow-up observations

The rapid dissemination of positions accurate to arcminutes makes the INTEGRAL/IBAS bursts prime candidates for follow-up observations in other wavelength bands.

We list in Table 1 the follow-up observations of GRB 040812 which have been reported so far in GCN, ATEL or IAU circulars. In the following sections we discuss the results of the substantial follow-up effort done on this burst.

4. X-ray observations

A first 10 ksec low energy X-ray observation of the field around the IBAS error box was carried out with the Chandra satellite 5 days after the burst and a second observation 10 days after the burst - both as "Directors discretionary time" observations with immediate public access to the data. The sky field containing GRB 040812 was not observable with the XMM satellite in the weeks following the burst due to pointing constraints.

The first Chandra observation using the ACIS-S camera revealed 4 sources above a threshold of 2.6 sigma inside the refined IBAS error circle, These sources are listed as source no 1 to 4 in Table 2.

By lowering the required significance level three additional sources were found inside the JEM-X error box, these are listed as source 5 to 7 in table 2. All the identified sources become more significant when the search energy band is increased to 0.1-10 keV.

The Chandra sources are indicated on Figure 2 with the IBAS and JEM-X error boxes overlaid. The brightest X-ray source in the image (source 2 in Table 2) is consistent with IBAS but outside the JEM-X error circle.

The second Chandra observation showed the brightest source from the first observation (source 2) to have faded by 30 %. The other sources from the first observation were too weak to make definite claims about variability. A new X-ray source (source 8 in Table 2) at a position consistent with GRB 040812 is visible in the second Chandra image.

Based on the Chandra observations source 2 appear as the most likely afterglow candidate related to GRB 040812. This conclusion supported by an analysis of the spectrum of the source (Campana and Moretti, GCN 2649)

Table 2. Chandra X-ray sources in the field around GRB 040812

No.	RA	Dec	Counts†	SNR	Counts†	SNR
			first observation		second observation	
1	16 26 0.47	-44 41 22.6	9	2.8	–	–
2	16 26 2.25	-44 43 49.4	57	6.9	38	5.4
3	16 26 6.48	-44 43 20.8	10	2.9	10	2.7
4	16 26 8.44	-44 41 25.2	33	5.0	33	5.2
5	16 25 54.65	-44 42 49.4	6	1.9	–	–
6	16 25 58.73	-44 41 47.0	4	1.9	–	–
7	16 26 1.21	-44 42 46.6	4	1.9	–	–
8	16 26 1.71	-44 43 27.9	–	—	16	3.7

All coordinates are given in J2000
† 0.5-8.0 keV band

5. Optical observations

GRB 040812 is located close to the Galactic plane (l: 337.9°, b: +3.1°) with an extinction in the I-band of $A_I \approx 2.3$ mag.

Optical observations of the GRB 040812 sky field were carried out very quickly after the IBAS trigger message from the Keck telescope on Hawai. The first images were obtained only 47 and 104 minutes after the burst (Berger et al., GCN 2644).

The position was also observed from Paranal using one of the VLT unit telescopes 17.5 hours and again 41.5 hours after the burst (D'Avanzo et al., GCN 2651).

The optical field is dominated by the bright foreground star HD 147812 (m_V=8.83) - see Figure reffinding. Unfortunately the position of the preferred X-ray afterglow source (source 2 from Table 2) is located only about 20″ from this star and the saturated stellar image is extending across the position of the X-ray source and prevents a deep optical analysis at this position.

Berger et al identifies sources 1, 3 and 7 in table 2 with stellar objects and sources 5 and 6 with stars or galaxies. They do not find optical counterparts for source 2 and 4. They note, however, that source 4 is 2″ away from a galaxy/stellar image.

Berger at al also notes that none of the optical counterparts exhibit any significant variability either between the two Keck epochs (taken 47 and 104 minutes after the burst) or between the Keck and LCO observations (taken 1.75 days after the burst).

In the case of the VLT observations, the disturbance from HD 147812 was anticipated prior to the observation and a mask was placed over the stellar image. Unfortunately the mask also covers the position of the Chandra source 2 position.

As a result of these unfortunate circumstances we have at present no useful data on the optical afterglow of GRB 040812.

A search using the ACF camera on HST and comparing two exposures taken 32 and 54 days after the burst has not revealed any variable source within 1 arcsecond of the putative Chandra X-ray afterglow candidates to a limiting magnitude of 27.0 (in filter FW775W) and 27.5 (in filter FW625W), respectively (Kulkarni et al., GCN #2824).

6. Infrared observations

Infrared (and optical) observations of the GRB 040812 sky field was carried out 18.4 hours after the burst an 1.3 m telescope at CTIO. The IR-images were compared to the 2MASS frames and no new sources could be seen to the limit of the comparison frames (Cobb et al., GCN #2642).

7. Radio observations

The IBAS error box for GRB 040812 was observed with the Very large Array 2 days after the burst (Soderberg et al., GCN # 2643). A single source was detected at 8.5 GHz with a flux of 0.45 mJy. The position of this source, RA: 16:26:08.5, dec: -44:41:04.0 (J2000) is consistent with the IBAS burst position - but clearly not at the position of the Chandra source 2 (see Figure reffinding).

Additional observations at 1280 MHz covering a larger field was done with the Indian Giant Metrewave Radio Telescope. One source was found which is possibly consistent with source 4 in the Chandra list (Bhattacharya et al., GCN #2653). The VLA source was not detected.

8. discussion

Still to come - contributions are welcome!

1) Where does this burst fall in the continuum of GRB light curves and spectral characteristics of the prompt emission?

2) Towards the X-ray rich side?

3) Do we see any significant spectral evolution?

Acknowledgements. The Danish Space Research Institute acknowledges the support given to the development of the JEM–X instrument from the PRODEX programme.

References

Winkler, C., Courvoisier, T.J.-L., DiCocco, G., et al. 2003 A&A (this volume)